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FIGHTING VEHICLES RESEARCH AND DEVELOPMENT ESTABLISHMENT

REPORT No. T.R. 80

FOURTH DEVELOPMENT FIRING TRIALS OF 81mm MORTAR IN A.P.C. F.V. 432 [C]

Chobham Lane,
Chertsey,
Surrey.

May 1966

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FIGHTING VEHICLES RESEARCH AND DEVELOPMENT ESTABLISHMENT

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ABSTRACT

This report describes a Fourth Development Firing Trial held at the Proof and Experimental Establishment, Pendine, in November, 1964, of the 81 mm Mortar on a floor mounted adapter fitted with a monopod in FV.432.

The vehicle was found to provide a remarkably steady and reliable platform for the 81 mm Mortar.

No difficulties of a physiological or physical nature were experienced when the vehicle was manned during the firing of all charges up to and including Charge 5 (Mk. 1 system).

It was found that the vehicle-mounted mortar had a 2% greater range and less dispersion than the ground mounted equipment for all charges up to and including Supercharge.

No defects of any significance occurred in the adapter.

The results indicated that the C2 sight is not robust enough for vehicle use on its present mounting.

CONTENTS

ORIGIN: Assistant Director, Tracked Vehicles (Project Co-ordination) Branch, F.V.R.D.E. under Project FV.432/K08/17/PC(T).

1. INTRODUCTION.

1.1 A successful development firing trial of a floor mounted adapter fitted with a monopod designed to permit the 81 mm Mortar to be fired from FV.432 was held at Netheravon in September, 1964, - see F.V.R.D.E. Report TR.76. This was followed by a routine proof firing trial for the Director of Inspectorate of Armaments who considered the adapter to have passed proof and that in consequence the vehicle was safe to be manned during the firing of the mortar (I. Arm. Report TP.272 refers).

1.2 This report describes a trial held at the Proof and Experimental Establishment, Pendine, in November, 1964, with the objects of resolving the physiological problems relating to the firing of the 81mm mortar from a FV.432, and of comparing the range and accuracy data of the vehicle-mounted mortar with those of a ground-mounted mortar.

1.3 At the time of this trial, clearance had not been given by the Director General of Artillery for the firing of Supercharge either from the ground-mounted or the vehicle-mounted mortar. Arrangements were, therefore, made to fire these charges by remote control.

1.4 After the trial had been planned, but prior to the commencement of the trial, it was agreed by the Director General of Artillery that there was no significant mortar-barrel to mortar-barrel variation, in consequence this possible variable was omitted from the firing programme.

2. METHOD.

2.1 Part I.

Preliminary non-manned firing. 12 bombs were fired from the equipment when the vehicle was located on a slope to check the installation and to assess any change of attitude of the vehicle after each bomb had been fired.

2.2 Part II.

Preliminary manned firing. 36 bombs were fired from a manned vehicle to practise the detachment in manning the vehicle and to permit the Army Personnel Research Establishment (A.P.R.E.) to obtain subjective assessments during firing.

2.3 Part III.

Endurance and assessment of the physiological effects of manning the vehicle during a prolonged firing programme. 160 bombs were fired in serials of 10 bombs at the rate of one bomb every 10 seconds with an interval of 15 minutes between serials. The mortar was fired at eight different azimuth angles and the position of the vehicle, located on a rough grass-covered sand dune, was changed on four occasions.

2.4 Part IV.

Range and Accuracy.

2.4.1 The range and accuracy of Charges 1, 3, 5 and Super, each at three quadrant elevations (QEs) were assessed under three conditions:-

Condition X. When fired from the vehicle, the mortar was relayed for each bomb.

Condition Y. The mortar was fired from the orthodox bipod and base in the ground-mounted role.

Condition Z. When fired from the vehicle, the mortar was not relayed between bombs in serials each comprised of 10 bombs.

2.4.2 The opportunity was taken during Part IV to obtain vehicle movement diagrams.

2.4.3 After each serial of 10 bombs, the vehicle was moved a few yards in order to simulate the taking up of a new firing position for each serial.

2.5 Part V.

Stability on Soft Sand. This was assessed by firing 20 bombs from the vehicle-mounted mortar when the vehicle was located on a soft drift sand slope.

2.6 For a full summary of the firing programme and serial identifications, see Appendix A.

3. RESULTS

3.1 Vehicle Stability.

3.1.1 It is convenient to consider the results obtained during Parts I, III, IV and V together insofar as the problem of vehicle stability is concerned.

3.1.2 Full details will be found in Appendix B.

3.1.3 From the results obtained, it can be deduced that vehicle stability and the amount of residual change in attitude due to the firing of the mortar depends on the surface of the ground on which the vehicle is located and the angle of tilt at which it is sited.

3.1.4 On nominally level ground it was found, during Part IV, that changes in vehicle attitude that occurred had no significant effect on the range or dispersion of the bombs.

3.1.5 On slopes it was found that the relative significance of the effect of residual changes in vehicle attitude on the performance of the mortar varied inversely as the range and that at long ranges (low QE) no significant effect on the external ballistic performance of the mortar due to vehicle movement was apparent.

3.1.6 It should be noted that many of the results quoted in Appendix B were obtained when the longitudinal axis of the vehicle was inclined at angles from $+10^{\circ}$ to -8° and the transverse axis on side slopes of $+10^{\circ}$ to -9°, during which the composite tilt exceeded the 10° maximum, for the correction of which provision has been made in the cross-levelling device in the adapter.

3.1.7 The siting of the vehicle on soft sand slopes at these somewhat excessive angles can be safely considered to be at the practical limiting conditions in that it is thought that any reasonable commander would not take up a fire position on similar adverse ground on slopes in excess of these referred to in para. 3.1.6.

3.1.8 Even under the difficult and possibly unrealistic firing positions chosen during the course of this trial, the evidence suggests that providing a check of the lay is made at the start of the firing of every 10 bombs, there would be no error separately recognisable within the overall dispersion of the bombs.

3.1.9 Velocities were recorded during Part V. The resultant calculated muzzle velocities were similar to those obtained during the Range and Accuracy Serials (Part IV) and it is therefore considered that the ground on which the vehicle is located has no effect on the internal ballistic performance of the vehicle-mounted mortar.

3.2 Part I.

The adapter was checked and found to be satisfactory; for details of the firing programme see Appendix B, Table B1.

3.3 Part II.

Preliminary manned firing. Subjective assessments of the accelerations at various locations on the adapter base and platform were made by A.P.R.E. who stated that the forces on the adapter resulting from the firing of Charges 3, 4 and 5 are unlikely to have any deleterious effect on the detachment in the vehicle. For detailed A.P.R.E. report see Appendix C.

3.4 Part III. Endurance and Assessment of the Physiological Effects.

3.4.1 Endurance. No difficulty was experienced in meeting the rate of fire of 6 bombs per minute.

Some minor faults developed: these are listed in Appendix H.

3.4.2 Physiological. Audiometry. After firing 160 bombs in 16 serials each of 10 bombs at the rate of one bomb every 10 seconds, i.e. 6 bombs per minute, with an interval of 15 minutes between serials, the hearing of the two men, wearing Ear Defenders Mk. 3, who manned the mortar in FV.432, underwent no detectable change. For detailed A.P.R.E. report see Appendix D.

3.4.3 Additional subjective assessment of the forces on the detachment were taken during the first two serials; the relevant detail is included in Appendix C.

3.5 Range and Accuracy

3.5.1 The range and accuracy serials were fired in order to compare the results of the vehicle-mounted mortar with those of the ground-mounted mortar and also to assess the stability of the vehicle-mounted equipment by firing similar serials with no relaying of the mortar between bombs in serials each of 10 bombs.

3.5.2 A summary of the salient range and accuracy results, which are fully corrected, of the vehicle-mounted mortar when the lay of the mortar was checked and if necessary relayed before each bomb was fired, is given in Table 1 below.

TABLE 1

Serial	QE Mils	Charge	Range m	SD Range m	SD Line m
31	800	1	931	22	3
34	1066		795	10	3
37	1333		467	5	3
40	800	3	2052	26	5
43	1066		1794	18	5
46	1333		1009	5	1
55	800	5	4575	28	8
58	1066		3723	27	5
61	1333		2267	19	13
70	800	Super	5080	42	30
73	1066		4376	46	42
76	1333		2643	27	9
Mean				23	10

3.5.3 In order to make comparison easier, the results obtained from the ground-mounted mortar (Condition Y) and those obtained from the vehicle-mounted equipment when the mortar was not checked or relayed between bombs in serials of ten bombs (Condition Z) are shown in Table 2 on the basis of the results shown in Table 1 being unity.

TABLE 2

Serial	Nominal QE mils	Charge	Condition Y Ground Mounted			Condition Z Vehicle-mounted No Relaying		
			Range		Line	Range		Line
			Mean	SD	SD	Mean	SD	SD
31-33	800	1	0.95	1.60	0.50	0.99	0.79	0.50
34-36	1066	1	0.98	0.78	0.50	1.00	1.78	1.00
37-39	1333	1	0.97	1.20	1.50	0.99	0.80	1.00
40-42	800	3	0.99	0.59	0.25	1.00	0.50	0.50
43-45	1066	3	0.98	0.69	0.50	0.98	1.44	0.75
46-48	1333	3	0.99	2.00	3.00	0.99	0.50	2.00
55-57	800	5	0.99	0.92	1.57	0.99	0.64	0.71
58-60	1066	5	0.98	2.61	0.75	1.01	0.78	1.00
61-63	1333	5	0.98	1.06	0.82	1.00	0.65	0.73
70-72	800	Super	0.99	1.84	1.12	1.00	0.81	0.31
73-75	1066	Super	0.99	1.70	0.92	0.99	0.45	0.35
76-78	1333	Super	0.96	2.17	1.12	0.98	1.09	1.62
Mean			0.98	1.43	1.05	0.99	0.85	0.87

It is evident from these results that the vehicle-mounted equipment has a 2% greater range than the ground-mounted equipment and is more consistent for range and line.

It is interesting to note that on the vehicle-mounted equipment, the results show less dispersion when the mortar has not been relayed between bombs in serials of 10 bombs.

3.5.4 Velocities were recorded by EVA (Electronic Velocity Analyser). The aerial for this equipment can be seen in Appendix M, Figure 4, midway between the ground-mounted mortar and FV.432. The summary of the results is shown in Table 3 below.

TABLE 3

Charge	Condition X Vehicle-mounted (f/s)			Condition Y Ground-mounted (f/s)		
	mv	Spread	SD	mv	Spread	SD
1	324	7	3	320	10	4
3	505	8	3	502	8	3
5	828	6	2	823	11	4
Super	902	8	3	893	12	5
1	Unity			0.98	1.4	1.6
3				0.99	1.0	1.0
5				0.99	1.8	2.0
Super				0.99	1.5	1.6

These results are consistent with those shown in Table 2 and indicate that the muzzle velocities of the vehicle-mounted mortar are about 1% greater than the muzzle velocities of the ground-mounted mortar and that the spread and dispersion (SD) of the muzzle velocities of the vehicle-mounted mortar are rather less than those of the ground-mounted mortar.

3.5.5 It will be of interest at this stage to compare the range and accuracy results of the 81mm mortar mounted in the U.S.A. Tracked APC T257E with results obtained from the corresponding U.K. equipment. The relevant information is shown in Table 4 below.

TABLE 4

Country	Charge	QE (mils)	Range m	SD m
U.K.	Super	800	5080	42
U.K.	5	800	4575	28
U.S.A.	8 (top)	800	3746	43

With the vehicle-mounted mortar results considered as unity the comparable results for the ground-mounted equipment are:

Country	Range	SD
U.K.	0.98	1.43
U.S.A.	0.97	3.00

(U.S.A. information extracted from Report DPS 1067 issued in October, 1963).

It is evident that the performance of the U.S.A. 81mm mortar in the U.S.A. tracked carrier, with its shorter maximum range compared to that of the U.K. equipment, follows the same trends as those which are applicable to FV.432.

3.5.6 For full details of the range and accuracy results, see Appendix E.

3.6 Traverse Efforts

3.6.1 The efforts required at the hand wheel to traverse the adapter platform were taken on three occasions, with the vehicle both on level ground and on a slope.

3.6.2 On level ground the mean effort at eight points of traverse was 5lbf both clockwise and anti-clockwise.

3.6.3 On a slope the efforts were 8 lbf clockwise and 6 lbf anti-clockwise.

3.6.4 It should be noted that these results, which are evidently satisfactory, were obtained over a period of 10 days during which the vehicle was subjected to blown sand and heavy rain.

3.6.5 For full details, see Appendix F.

3.7 Barrel Clamp

3.7.1 The movement of the barrel clamp was measured after each bomb in Serials 1 - 6, and after every 10 bombs in Serials 13 - 86.

3.7.2 The correct adjustment for the closing effort, 35 lbf, was applied before the trial commenced, and again during the trial after the effort had decreased to 26 lbf. The effort thereafter varied between 30 and 37 lbf but no further adjustments were made.

3.7.3 The maximum movements of the barrel clamp are given in Table 5 below.

TABLE 5

Charge	Condition of Clamp	Amount of Movement in inches at indicated QE		Serial
		QE 800 mils	QE 1333 mils	
5	Soft	-0.10	-0.10	5, 6.
1	Hard	-0.10	-0.05	31, 37.
3	Hard	Nil	-0.05	46.
5	Hard	+0.30	Nil	58.
Super	Hard	+1.20	+0.60	70, 76.

Note: The 'Hard' setting is that normally used. In the 'Soft' setting, the pressure of the clamp round the barrel has been relieved in order to permit the barrel to slide through the clamp during bedding-in operations with the ground-mounted equipment without unduly disturbing the lay of the mortar.

3.7.4 The significance of this movement can be judged by the following information:

At a QE of 1333 mils with Charge 5, a 1 inch movement of the barrel clamp will represent about 200 metres change in range.

At a QE of 800 mils with Charge 5, a 1 inch movement of the barrel clamp will represent about 15 metres change in range.

The significance therefore increases with an increase of QE.

3.7.5 For details of the barrel clamp movement, see Appendix G.

3.7.6 It is interesting to record that in the ground-mounted equipment a considerable barrel clamp movement takes place during bedding-in, and thereafter the average movement is approximately 0.10 inch per bomb.

3.8 Defects

3.8.1 The only serious defect which occurred to the equipment during this trial was the failure of the C2 sight: for details see para. 3.9.

3.8.2 The other defects which occurred were all of a minor nature and are listed in Appendix H.

3.8.3 The most persistent of the defects occurred either to the azimuth ring or to the mortar heading plate.

3.8.4 A diagram will be found in Appendix H showing the relationship between the azimuth ring, the mortar heading plate and the vehicle heading plate.

3.9 Sights

3.9.1 Two C2 sights were used during this trial, No. 82 for 284 bombs and No. 101 for 165 bombs.

3.9.2 Both sights were damaged during the course of the trial and unfortunately sight No. 82 was rendered unserviceable by accidental damage during its removal from the mounting.

3.9.3 Sight No. 101 was still in use when the trial was completed.

3.9.4 The sights were inspected by D.I. Arm (Fire Control Instruments) after the trial when it was discovered that the sights suffered a common failure in that the elevation and azimuth worm shafts in both sights were bent.

3.9.5 For full details as to the incidents which happened to the sights during the course of the trial and the D.I. Arm (FCI) report, see Appendix J.

4. MISCELLANEOUS INFORMATION.

Notes on a misfire, mounting buffers, barrel buffers and throw-over link will be found in Appendix K.

5. EQUIPMENT

Details will be found in Appendix L.

6. PHOTOGRAPHS

The following photographs will be found in Appendix M.

Figs. 1 - 2 The vehicle in position prior to the commencement of Part III (Endurance and Assessment of Physiological Effects).

Fig. 3 The detachment from 2nd Bn The Parachute Regiment who manned the vehicle during Part III.

Fig. 4 The lay out of the firing point for Part IV (Range and Accuracy).

Figs. 5 - 7 The laying, loading and firing positions of the layer and loader in FV.432.

7. CONCLUSIONS

The following conclusions are made from the results of these trials.

7.1 FV.432 provides a remarkably steady and reliable platform for the firing of the 81 mm mortar.

7.2 No difficulties, either physiological or physical, were experienced in manning the vehicle during the firing of all charges up to and including Charge 5 (Mk. 1 system).

7.3 It was found that the vehicle-mounted mortar has 2% greater range than the ground-mounted equipment and it is more consistent in ranging for all charges including Supercharge.

7.4 No defects of any significance occurred in the adapter.

7.5 The C2 sight units were not robust enough to withstand the shock loads to which they were subjected in the vehicle.

7.6 The facts that the vehicle makes a very steady platform for the mortar and that any residual change in attitude of the vehicle has for the most part an insignificant effect on range and consistency suggest that a possible requirement for the C2 sight to be removed during firing would not result in any deterioration in the overall efficiency of the weapon system.

FIRING PROGRAMME AS PLANNED
Identification of Serial Numbers

Part I. Preliminary unmanned firing.

Serial	Charge	Bombs	QE (mils)	Trav. Angle (mils)
1	5	2	1333	0
2	5	2	897	0
3	P1	2	1333	0
4	P1	2	901	0
5	5	2	1333	0
6	5	2	895	0

Part II. Preliminary manned firing.

Serial	Charge	Bombs	QE (mils)	Trav. Angle (mils)
7	3	6	1333	0
8	3	6	931	0
9	4	6	1333	800
10	4	6	895	800
11	5	6	1333	800
12	5	6	895	800

Part III. Endurance and assessment of the physiological effects.

Serial	Charge	Bombs	QE (mils)	Trav. Angle (mils)
13	5	10	1333	0
14	5	10	910	0
15	5	10	1333	800
16	5	10	910	800
17	5	10	1333	1600
18	5	10	910	1600
19	5	10	1333	2400
20	5	10	910	2400
21	5	10	1333	3200
22	5	10	900	3200
23	5	10	1333	4000
24	5	10	900	4000
25	5	10	1333	4800
26	5	10	900	4800
27	5	10	1333	5600
28	5	10	900	5600

Part IV. Range and accuracy.
Condition X - mortar mounted in FV.432 relaying for each bomb.
Condition Y - mortar on ground mount.
Condition Z - mortar mounted in FV.432 no relaying between bombs in a serial.

Serial	Charge	Bombs	QE (mils)	Trav. Angle	Condition
31	1	10	800	0	X
32	1	10	800	0	Y
33	1	10	800	0	Z
34	1	10	1066	0	X
35	1	10	1066	0	Y
36	1	10	1066	0	Z
37	1	10	1333	0	X
38	1	10	1333	0	Y
39	1	10	1333	0	Z
40	3	10	800	0	X
41	3	10	800	0	Y
42	3	10	800	0	Z
43	3	10	1066	0	X
44	3	10	1066	0	Y
45	3	10	1066	0	Z
46	3	10	1333	0	X
47	3	10	1333	0	Y
48	3	10	1333	0	Z
55	5	10	800	0	X
56	5	10	800	0	Y
57	5	10	800	0	Z
58	5	10	1066	0	X
59	5	10	1066	0	Y
60	5	10	1066	0	Z
61	5	10	1333	0	X
62	5	10	1333	0	Y
63	5	10	1333	0	Z
70	Super	10	800	0	X
71	Super	10	800	0	Y
72	Super	10	800	0	Z
73	Super	10	1066	0	X
74	Super	10	1066	0	Y
75	Super	10	1066	0	Z
76	Super	10	1333	0	X
77	Super	10	1333	0	Y
78	Super	10	1333	0	Z

Plus 3 Supercharge and 2 Charge 5 sighters.

Part V. Stability on soft sand.

Serial	Charge	Bombs	QE (mils)	Trav. Angle (mils)
85	Super	10	1333	0
86	Super	10	800	0

Note: Serials 29-30, 49-54 and 64-69 were included in the original Plan of Test to allow for barrel to barrel variation but were not fired (see para. 1.4).

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APPENDIX A
Sheet 2

Summary of Bombs fired from FV.432

Part	Charge							
	1	3	4	5	5 (Sighters)	Super	Super (Sighters)	PM
I				8				4
II		12	12	12				
III				160				
IV	60	60		60	2	60	3	
V					2	20	3	
Total	60	72	12	240	4	80	6	4
Grand Total								478

Summary of Bombs fired from Ground-mounted Mortar

Part	Charge			
	1	3	5	Super
IV	30	30	30	30
Sighters			2	3
Total				125

STABILITY

B 1 It is convenient to consider the results obtained during Parts I, III, IV and V together insofar as the problem of vehicle stability is concerned.

B 2 The amount of residual movement of the vehicle will govern the consistency of the location of the fall of bomb in the impact area when the mortar is not relayed between bombs.

B 3 The amount of residual movement was therefore determined over a variety of surfaces and on a variety of slopes as shown below.

Part I — Preliminary unmanned firing: vehicle located on marram grass-covered sand dunes.

Part III — Endurance, from a manned vehicle: terrain as for Part I.

Part IV — Range and Accuracy: vehicle located on hard level ground.

Part V — Stability on soft drift sand slopes.

B 4 The vehicle attitude was measured by means of an inspector's clinometer mounted on 'Vee' blocks placed on 4-inch diameter tubes, one welded on the fore and aft axis, and the other transversely at the front of the vehicle.

B 5 The changes in the vehicle attitude and the resultant calculated error in the impact area are shown in Table B1.

TABLE B1

Record of Vehicle Movements and Effects on Range

Part No.	Sequence of Recordings	Serial No.	QE	Charge	Trav. Angle	Vehicle Attitude						Accumulated Calculated Error In Impact Area (m) per Serial	
						Front			Left Side				
			mils		mils		°	'	mils	°	'	mils	Range	Line
I	Before	1				U	9	52	175.6	U	1	12	21.4		
	After 2 bombs	1	1333	5	5600	U	10	1	178.1	U	1	15	22.3	< 10	10
	" " "	2	897	5		U	10	3	178.7	U	1	17	22.9	< 10	10
	" " "	3	1333	P1		U	10	7	179.9	U	1	17	22.9	< 10	< 10
	" " "	4	901	P1		U	10	8	180.2	U	1	17	22.9	< 10	< 10
	" " "	5	1333	5		U	10	8	180.2	U	1	17	22.9	Nil	Nil
	" " "	6*	895	5		U	10	10	180.8	U	1	17	22.9	< 10	< 10
III	Before	13				U	5	31	98.2	D	6	15	111.2		
	After 10 bombs	13	1333	5	0	U	5	38	100.3	D	6	15	111.2	15	Nil
	" " "	14	910	5	0	U	5	39	100.6	D	6	16	111.5	< 10	< 10
	" " "	15	1333	5	800	U	5	45	102.4	D	6	24	113.9	< 10	< 10
	" " "	16*	910	5	800	U	5	48	103.3	D	6	27	114.8	< 10	< 10
	Before	17				U	2	3	36.5	D	8	52	157.8		
	After 10 bombs	17	1333	5	1600	U	2	7	37.7	D	8	44	155.4	15	10
	" " "	18	910	5	1600	U	2	3	36.5	D	8	37	153.3	< 10	10
	" " "	19	1333	5	2400	U	2	1	35.9	D	8	37	153.3	< 10	< 10
	" " "	20*	910	5	2400	U	1	57	34.7	D	8	34	152.4	< 10	< 10
	Before	21				D	7	57	141.5	U	2	48	50.0		
	After 10 bombs	21	1333	5	3200	D	7	51	139.7	U	2	52	51.2	16	< 10
	" " "	22	900	5	3200	D	7	53	140.3	U	2	50	50.6	< 10	< 10
	" " "	23	1333	5	4000	D	7	53	140.3	U	2	54	51.8	< 10	< 10
	" " "	24*	900	5	4000	D	7	53	140.3	U	2	55	52.1	< 10	< 10

TABLE B1 (Continued)

Part No.	Sequence of Recordings	Serial No.	QE M	Charge	Trav. Angle M	Vehicle Attitude: Front				Vehicle Attitude: Left Side				Accumulated Calculated Error In Impact Area (m) per Serial: Range	Accumulated Calculated Error In Impact Area (m) per Serial: Line
							°	'	M		°	'	M		
III	Before	25				D	1	35	28.3	U	9	49	174.7		
Cont.	After 10 bombs	25	1333	5	4800	D	1	34	28.0	U	9	38	171.4	25	< 10
	" " "	26	900	5	4800	D	1	22	24.4	U	9	37	171.1	< 10	15
	" " "	27	1333	5	5600	D	1	1	18.1	U	9	23	166.9	< 10	60
	" " "	28*	900	5	5600	D	1	1	18.1	U	9	11	163.3	< 10	10
IV	Before	31				D	0	33	9.9	U	2	21	41.9		
	After 10 bombs	31	800	1	0	D	0	33	9.9	U	2	21	41.9	Nil	Nil
	Before	33				D	0	33	9.9	U	2	21	41.9		
	After 10 bombs	33*	800	1	0	D	0	31	9.3	U	2	21	41.9	< 10	Nil
	Before	34				D	0	37	11.1	U	2	21	41.9		
	After 10 bombs	34*	1066	1	0	D	0	35	10.5	U	2	20	41.6	< 10	< 10
	Before	36				D	0	35	10.5	U	2	20	41.6		
	After 10 bombs	36*	1066	1	0	D	0	33	9.9	U	2	21	41.9	< 10	< 10
	Before	37				D	0	42	12.6	U	2	40	47.6		
	After 10 bombs	37	1333	1	0	D	0	41	12.3	U	2	44	48.8	< 10	< 10
	Before	39				D	0	41	12.3	U	2	44	48.8		
	After 10 bombs	39*	1333	1	0	D	0	39	11.7	U	2	44	48.8	< 10	< 10
	Before	46				D	0	45	13.5	U	2	38	47.0		
	After 10 bombs	46	1333	3	0	D	0	41	12.3	U	2	37	46.7	< 10	< 10
	Before	48				D	0	41	12.3	U	2	37	46.7		
	After 10 bombs	48*	1333	3	0	D	0	40	12.0	U	2	37	46.7	< 10	Nil
	Before	40				D	0	20	6.0	U	2	58	53.0		
	After 10 bombs	40*	800	3	0	D	0	24	7.2	U	3	1	53.6	< 10	< 10
	Before	42				D	0	19	5.7	U	3	1	53.6		
	After 10 bombs	42*	800	3	0	D	0	22	6.6	U	3	2	54.2	< 10	< 10
	Before	43				D	0	22	6.6	U	2	59	53.3		
	After 10 bombs	43*	1066	3	0	D	0	25	7.5	U	2	58	53.0	< 10	< 10
	Before	45				D	0	23	6.9	U	2	58	53.0		
	After 10 bombs	45*	1066	3	0	D	0	25	7.5	U	2	58	53.0	< 10	Nil
	Before	70				D	0	18	5.4	U	2	59	53.3		
	After 10 bombs	70*	800	S	0	D	0	22	6.6	U	3	2	54.2	< 10	< 10
	Before	72				D	0	17	5.1	U	2	58	53.0		
	After 10 bombs	72*	800	S	0	D	0	17	5.1	U	2	58	53.0	Nil	Nil
	Before	73				D	0	27	8.1	U	2	22	42.2		
	After 10 bombs	73*	1066	S	0	D	0	22	6.6	U	2	23	42.5	<10	<10
	Before	75				D	0	25	7.5	U	2	26	43.4		
	After 10 bombs	75*	1066	S	0	D	0	24	7.2	U	2	27	43.7	<10	<10
	Before	76				D	0	25	7.5	U	2	27	43.7		
	After 10 bombs	76*	1333	S	0	D	0	22	6.6	U	2	27	43.7	<10	Nil
	Before	78				D	0	19	5.7	U	2	22	42.2		
	After 10 bombs	78*	1333	S	0	D	0	18	5.4	U	2	19	41.3	<10	<10
	Before	61				D	0	19	5.7	U	2	21	41.9		
	After 10 bombs	61*	1333	5	0	D	0	19	5.7	U	2	21	41.9	Nil	Nil
	Before	63				D	0	25	7.5	U	2	26	43.4		
	After 10 bombs	63*	1333	5	0	D	0	23	6.9	U	2	28	44.0	<10	<10
	Before	58				D	0	23	6.9	U	2	26	43.4		
	After 10 bombs	58*	1066	5	0	D	0	21	6.3	U	2	25	43.1	<10	<10
	Before	60				D	0	22	6.6	U	2	24	42.8		
	After 10 bombs	60*	1066	5	0	D	0	19	5.7	U	2	25	43.1	<10	<10
	Before	55				D	0	16	4.8	U	2	26	43.4		
	After 10 bombs	55*	800	5	0	D	0	11	3.3	U	2	26	43.4	<10	Nil
	Before	57				D	0	7	2.1	U	2	26	43.4		
	After 10 bombs	57	800	5	0	D	0	3	0.9	U	2	22	42.2	<10	<10

TABLE B1 (Continued)

Part No.	Sequence of Recordings	Serial No.	QE ✓1	Charge	Trav. Angle	Vehicle Attitude								Accumulated Calculated Error in Impact Area (m) per Serial	
						Front				Left Side					
					✓1		°	'	✓1		°	'	✓1	Range	Line
V	Before	85				D	3	10	56.3	U	8	38	153.6		
	After 3 bombs	85	1333	5	3200	D	2	57	52.7	U	8	29	150.9	25	20
	After 7 bombs		1333	S	3200	D	2	42	48.2	U	8	28	150.6	60	20
	After 3 bombs	*	1333	S	3200	D	2	40	47.6	U	8	18	147.6	60	50
	Before	86				D	3	29	62.0	U	8	9	144.9		
	After 2 bombs	86	800	5	3200	D	3	21	59.6	U	8	3	143.1	< 10	< 10
	After 3 bombs	**	800	S	3200	D	3	17	58.4	U	8	2	142.8	< 10	< 10
	After 7 bombs		800	S	3200	D	3	12	56.9	U	7	58	141.6	< 10	15

*Vehicle position changed after this Serial.
**Vehicle was found to have moved 2 inches sideways.

B 6 The significance of the results shown in the foregoing table can best be evaluated by considering Range Table parameters for the service charges (Charge 5, Mk.1 system, Charge 6 Mk.2 system) (Temporary Range Tables Ref. AAB/51/02 dated 29th July, 1965):-

At a QE of 880 mils, 5.9 mils variation in QE represents 10m in range.
At a QE of 1333 mils, 1.4 mils variation in QE represents 10m in range.
The 90% probability zones under ideal conditions of firing are range 145m, breadth 50m.

B 7 It can be deduced from the results shown in Table B1 that vehicle stability, when the 81mm mortar is being fired, depends on the surface of the ground on which the vehicle is located and the angle of tilt at which it is sited, and that the significance of the effect of vehicle movement on the performance of the mortar varies inversely on the range and that at long ranges (low QE) it seems probable that no significant effect on the ballistic performances of the mortar, due to vehicle movement, is likely to occur.

B 8 Another factor which should be taken into consideration is that the permitted tolerance for accuracy of the C2 sight is ±2 mils. This is greater than any residual vehicle movement recorded during Part IV and may explain why greater consistency was obtained during the firing of 10 bombs when no relaying took place between bombs in a serial of 10 bombs (see para. 3.4.3, Table 2).

B 9 Hull Movements.

9.1 During the Range and Accuracy serials (Part IV), hull movements were recorded by means of the scribe-plate technique.

9.2 Aluminium plates 3¾ inches by 3¾ inches were attached to the side of the vehicle hull over the front and rear road wheels.

9.3 A stout steel stanchion was fixed to the ground; a hard steel spring loaded scriber attached to the stanchion was adjusted to bear on the surface of the aluminium plates.

9.4 When the mortar was fired, the pattern of the vehicle hull movement was recorded by the steel scribe on the aluminium plate.

9.5 For the results see the Annex to this Appendix.

9.6 It will be seen that the maximum vertical movement of the vehicle during firing was approximately 0.4 inches and that the angular movement of the vehicle during firing was only 6 mils, the effect of which is insignificant.

9.7 The residual movements of the vehicle due to firing are too small to recognise on the vehicle movement diagrams. As will be seen from Table B1 the residual movements were small and would have an insignificant effect on range and accuracy.

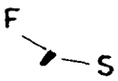
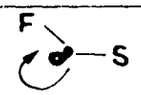
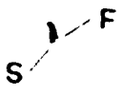
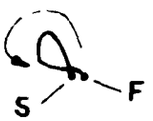
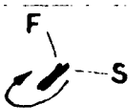
B 10 The velocities were recorded during Serials 85 and 86 by means of EVA equipment. The results are shown in Table B2 below.

TABLE B2

Serial	MV (f/s)	SD (f/s)	Spread (f/s)
85 86	908 901	3 2	11 9
Mean of R & A Serials (31 - 78) (Part iV)	900	3	9

In view of the similarity in the results obtained during Serials 85 and 86, and those obtained during the Range and Accuracy Serials, it is considered that ground on which the vehicle is located has no effect on the internal ballistic performance of the vehicle-mounted mortar.

ALUMINIUM PLATES WERE FITTED ON THE LEFT SIDE OF THE VEHICLE ON THE HULL ABOVE THE FRONT AND REAR ROAD WHEELS. HULL MOVEMENTS WERE RECORDED BY MEANS OF STEEL SCRIBERS, FITTED TO SUBSTANTIAL STANDS, ACTING UPON THE ALUMINIUM PLATES.
THE RECORDS FOR CHARGE 3, 5 & SUPER ARE SHOWN BELOW

SERIAL	CHARGE	QE (MILS)	FRONT	REAR
42/4	3	800		
45/4		1066		
48/2		1333		
55/2	5	800		
58/6		1066		
61/6		1333		
72/1	SUP	800		
73/4		1066		
76/3		1333		

S = START F = FINISH SCALE 1/1

VEHICLE MOVEMENT DIAGRAMS

FIGHTING VEHICLES RESEARCH AND

REPORT N°
TR 80
ANNEXURE TO
APPENDIX B

SUBJECTIVE ASSESSMENTS
BY
DR. M.A. ELWOOD, A.P.R.E.

C 1 Subjective assessments were made of tolerance for the forces applied to the human body (fingers, feet and knees), by parts of the mounting where men were likely to be in contact. The results of previous measurements of accelerations were available to identify the probable trouble spots.

C 2 The firing of Charge 5 applied forces to the feet of personnel standing on the platform or the corners of the mount. These are unlikely to have any deleterious effect and were described as having less effect than the forces applied to the feet when bedding-in a mortar on the ground.

C 3 During the firing of Charge 5 a brief survey was made of sites where personnel (particularly extra passengers) could make contact with the mounting. On an acute basis it would seem that personnel should be warned not to kneel on the front corner of the mounting under the muzzle.

C 4 For details see Annex to this Appendix.

Summary of Subjective Assessment of Accelerations during Part II

Serial QE Charge Traverse	Bomb	Subject	Site	Bodily Contact	Padding	Remarks
7 1333 mils 3 0 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "
8 931 mils 3 0 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "
9 1333 mils 4 800 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "
10 895 mils 4 800 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "
11 1333 mils 5 800 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "
12 895 mils 5 800 mils	1 to 3 1 to 2 3 4 to 6 4 to 6 4 to 6	4 (Loader) 3 (Layer) 3 1 (Layer) 2 (Loader) 5	Platform " Rear Corner Platform " Rear Corner	Feet " " " " "	Nil " " " " "	Acceptable " " " " "

NOTE: Subjects 1, 2 and 5 wore boots D.M.S.
Subjects 3 and 4 wore light civilian shoes.

Summary o

Serial QE Charge Traverse	Bomb
26 900 mils 5 4800 mils	1 2 3 4 6 7 8 9 10
27 1333 mils 5 5600 mils	1 2 3 4 5 6 7 8 to 10

NOTE: Subject 3 w
his knee, n

during Part II

Padding	Remarks
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"
Nil	Acceptable
"	"
"	"
"	"
"	"
"	"

Summary of Subjective Assessment of Accelerations during Part III

Serial QE Charge Traverse	Bomb	Subject	Site	Bodily Contact	Padding	Remarks
26	1	3	Platform	Knee	Rubber Pad	Acceptable
900 mils	2	3	"	Fingers	Nil	"
5	3	3	"	Knee - light pressure	"	"
4800 mils	4	3	"	Knee - heavy pressure	"	"
	6	3	Front Corner	Foot - light pressure	"	"
	7	3	" "	Foot - heavy pressure	"	"
	8	3	" "	Knee	Rubber Pad	"
	9	3	" "	Knee - minimum pressure	Nil	"
	10	3	" "	Knee - moderate pressure	"	Unpleasant but Acceptable
27	1	3	Front Corner	Foot - minimum pressure	Nil	Acceptable
1333 mils						
5	2	3	" "	Foot - heavy pressure	"	"
5600 mils	3	3	" "	Fingers	"	"
	4	3	" "	Knee	Rubber Pad	"
	5	3	" "	Knee - minimum pressure	Nil	Unpleasant but Acceptable
	6	3	" "	Knee - moderate pressure	"	Slight pain
	7	3	" "	Knee - moderate pressure	"	Slight pain
	8 to 10	Not assessed				

NOTE: Subject 3 wore light civilian shoes. He had two layers of clothing over his knee, namely thin trousers and a waterproof overgarment.

AUDIOMETRY

By

DR. M.A. Elwood, A.P.R.E.

D 1 After firing 160 bombs in 16 serials of 10 bombs in 1½ minutes each, the hearing of the two men who had manned the mortar in FV.432, while wearing Defenders Ear Mk. 3, underwent no detectable change. Their ears were about ten inches below the muzzle. Two cycles of audiometric tests were commenced 1½ and 6½ minutes after each serial. The exposed ear was tested first. For the timed programme see Annex 1 to this Appendix and for the results of the audiometric tests see Annex 2, audiograms in the range of 1.5 to 6 K c/s, and Annex 3 complete audiograms (0.25 to 8.0 K c/s).

D 2 It is recommended that manned firings continue with men wearing Defenders Ear Mk. 3 unless hearing is monitored in an experiment with other forms of protection.

D 3 It should be emphasised that an 81 mm Mortar fired from the ground constitutes a hazard for unprotected ears. There is limited evidence which suggests that the Defender Ear Mk. 3 will give adequate protection in this situation. The existing communication headset may provide some protection, but there is too little evidence to assess its efficiency.

D 4 The subjects were No. 1, the Layer, L/c Parker, No. 2, the Loader, Pte Phipps, both of 2nd Bn The Parachute Regiment.

REPORT TR.80
APPENDIX D
ANNEX 1

81mm MORTAR MOUNTED IN FV.432

Timing of Experimental Programme

Serial	Number of Bombs	Bomb Timings		Test Cycle Timings	
		First	Tenth	First	Second
13	10	09.59.00	10.00.30	10.02.00	10.07.00
14	10	10.15.30	10.17.00	10.18.30	10.23.30
15	10	10.31.30	10.33.00	10.34.30	10.39.30
16	10	10.47.00	10.48.30	10.50.00	10.55.00
17	10	11.03.30	11.05.00	11.06.30	11.11.30
18	10	11.20.00	11.21.30	11.23.00	11.28.00
19	10	11.36.00	11.37.30	11.39.00	11.44.00
20	10	11.55.00*	11.56.30	11.58.00	12.03.00
21	10	12.11.00	12.12.30	12.14.00	12.19.00
22	10	12.27.30	12.29.00	12.30.30	12.35.30
23	10	12.44.00	12.45.30	12.47.00	12.52.00
24	10	13.00.30	13.02.00	13.03.30	13.08.30
25	10	13.17.00	13.18.30	13.20.00	13.25.00
26	10	13.33.30	13.35.00	13.36.30	13.41.30
27	10	13.50.00	13.51.30	13.53.00	13.58.00
28	10	14.06.30	14.08.00	14.09.30	14.21.30**

*Delay in programme of $2\frac{1}{2}$ minutes and later made up.
**Full audiograms taken after final firings.

REPORT TR.80
APPENDIX D
ANNEX 3

Complete Audiograms (in db) November, 1964.

Subject and EAR	Date	Time	Frequency K c/s								
			0.25	0.50	1.00	1.50	2.00	3.00	4.00	6.00	8.00
No. 1 LEFT	3 Nov	-	15	15	15	15	20	30	55	30	25
	11 Nov	09.30	5	10	0	5	10	20	55	35	25
		14.10	10	15	5	5	10	20	55	45	25
		14.22	5	10	5	5	10	25	55	40	30
No. 1 RIGHT	3 Nov	-	30	25	15	10	25	15	25	0	5
	11 Nov	09.30	10	10	5	5	15	10	20	5	20
		14.10	10	15	5	10	20	15	25	5	5
		14.22	10	15	10	10	20	10	25	5	10
No. 2 LEFT	3 Nov	-	25	15	10	5	10	10	5	0	0
	11 Nov	09.30	0	0	-5	-5	-5	0	0	5	-5
		14.10	5	0	0	0	5	0	5	5	-5
		14.22	0	0	-5	-5	5	5	10	10	-5
No. 2 RIGHT	3 Nov	-	25	25	10	15	15	10	0	5	15
	11 Nov	09.30	10	-5	-5	0	-5	-5	-5	5	10
		14.10	0	-5	-5	0	0	-5	0	0	10
		14.22	0	0	-5	5	0	-5	5	0	10

REPORT TR.80
APPENDIX D
ANNEX 2

Audiograms (in db) in the Range 1.5 to 6 K c/s

Date 1964	Time	Subject No. 1										Subject No. 2									
		Left Ear* (Kc/s)					Right Ear (Kc/s)					Left Ear (Kc/s)					Right Ear* (Kc/s)				
		1.5	2	3	4	6	1.5	2	3	4	6	1.5	2	3	4	6	1.5	2	3	4	6
3 Nov		15	20	30	55	30	10	25	15	25	0	5	10	10	5	0	15	15	10	0	5
10 Nov	1130 00	-	10	25	55	40	-	15	10	20	0	-	5	0	5	5	-	5	0	0	5
	1540 00	10	10	25	50	35	5	15	10	20	10	0	10	5	5	5	0	0	0	0	10
11 Nov	0930 00	5	10	20	55	35	5	15	10	20	5	-5	-5	0	0	5	0	-5	-5	-5	5
	1002 00	5	10	25	55	35	5	15	5	20	0	-5	5	5	5	5	0	0	0	5	5
	1007 00	0	5	25	55	35	5	15	5	20	-5	0	5	5	5	5	0	0	5	5	10
	1018 30	5	5	25	55	45	0	15	10	20	0	0	5	5	5	5	-5	0	-5	0	0
	1023 30	5	5	25	55	35	5	15	5	20	0	0	5	0	5	5	-10	0	-5	0	0
	1034 30	5	10	20	55	35	5	20	10	20	0	0	5	5	5	5	0	0	-5	0	5
	1039 30	5	5	25	55	40	5	15	10	20	5	0	5	5	5	0	-5	0	-5	0	5
	1050 00	5	10	20	55	40	5	15	10	20	10	-5	5	5	5	0	0	0	0	5	0
	1055 00	5	10	20	55	35	5	15	10	25	10	-5	5	5	0	0	0	0	-5	5	0
	1106 30	10	15	25	55	40	5	20	10	25	5	-5	0	5	0	10	0	0	0	0	0
	1111 30	5	10	25	55	45	5	15	10	25	5	-5	5	0	0	5	-5	0	-5	0	0
	1123 00	10	15	25	50	40	5	20	10	25	0	-5	0	0	0	5	-5	0	-5	0	-5
	1128 00	5	10	25	55	40	5	15	10	20	5	-5	0	5	5	10	0	0	0	5	0
	1139 00	5	15	25	55	40	5	20	10	20	5	0	5	0	5	5	0	0	-5	0	5
	1144 00	5	15	25	55	35	5	20	5	20	0	0	5	0	5	10	-5	0	-5	5	5
	1158 00	5	10	25	50	40	0	15	10	20	0	-5	5	5	0	15	-5	5	-5	0	10
	1203 00	5	10	25	55	40	5	15	10	20	5	-5	5	0	0	10	-5	0	-5	0	5
	1214 00	5	10	20	55	40	5	20	5	20	0	5	5	5	5	10	0	5	0	5	5
	1219 00	5	10	25	55	40	5	20	10	20	-5	-5	5	0	0	10	-5	5	5	0	0
	1230 30	5	10	20	55	40	5	20	5	20	0	0	5	0	5	15	0	5	-5	5	0
	1235 30	0	10	25	55	40	5	20	5	20	0	-5	5	5	5	10	-5	0	-5	5	0
	1247 00	5	10	20	55	45	5	20	5	20	0	5	5	5	0	5	0	5	0	0	5
	1252 00	0	10	25	55	45	5	20	10	25	-5	-5	5	0	0	5	-5	0	-5	5	0
	1303 30	5	10	25	55	45	5	20	10	20	10	0	0	0	5	10	0	0	-5	5	0
	1308 30	5	10	25	55	45	5	20	10	20	5	-5	5	5	5	5	-5	0	-5	5	0
	1320 00	5	10	25	55	40	10	25	10	20	-5	-5	10	5	0	5	0	5	0	0	5
	1325 00	5	10	25	55	40	5	20	10	25	-5	-5	5	5	0	5	0	0	0	5	5
	1336 30	10	10	25	55	35	10	20	10	20	-5	0	5	0	5	10	0	0	0	0	5
	1341 30	10	10	25	55	35	5	20	10	20	-5	-5	5	5	0	5	-5	0	-5	0	5
	1353 00	10	15	25	55	45	10	20	10	25	20	-5	0	0	5	10	0	0	0	0	5
	1358 00	5	10	25	55	45	10	20	5	25	10	-5	5	0	0	5	-5	-5	-5	0	0
	1409 00	5	10	20	55	45	10	20	15	25	5	0	5	0	5	5	0	0	-5	0	0
	1421 30	5	10	25	55	40	10	20	10	25	5	-5	5	5	10	10	5	0	-5	5	0

*This was the more exposed ear and was tested first.

PART IV DETAILED R & A RESULTS

Bombs: 81mm filled HE substitute fuzed 162 inert.
Temperature: controlled at 70°F.
Bomb weight: 9.31 lb.
Condition x: Fired from FV.432.
y: Fired from ground mounting.
z: Fired from FV.432 - no relaying between bombs in a serial of 10 bombs.

Serial (10 bombs)	Condition	Charge	QE (M)	Corrected MV (f s)	md MV	Corrected Range (m) at MV Realised	md Range (m)	md Line (m)	$\kappa\sigma$ (mortar law)	Co
31	x	1	809	327	3	931	17	2	1.122	0.816
32	y		809	320	3	885	28	1	1.260	0.725
33	z		809	322	3	922	14	1	0.855	1.067
34	x		1077	324	1	795	8	2	0.865	1.058
35	y		1074	320	2	777	6	1	0.875	1.044
36	z		1077	325	1	796	15	2	0.905	1.012
37	x		1335	322	2	467	5	2	0.550	1.663
38	y		1333	320	3	455	5	3	0.810	1.127
39	z		1336	321	2	465	4	2	0.545	1.677
40	x	3	804	505	3	2052	20	4	1.010	0.908
41	y		804	505	2	2035	12	1	1.040	0.882
42	z		804	506	2	2054	10	2	1.000	0.915
43	x		1071	510	2	1794	15	4	0.935	0.978
44	y		1071	506	2	1750	10	2	1.015	0.904
45	z		1072	505	3	1759	21	3	0.955	0.960
46	x		1342	500	1	1009	4	1	0.765	1.195
47	y		1340	495	3	996	7	3	0.760	1.207
48	z		1342	501	1	1001	2	2	0.840	1.092
55	x	5	803	828	2	4575	23	6	0.890	1.028
56	y		803	822	3	4516	21	10	0.900	1.017
57	z		803	828	2	4536	15	5	0.920	0.997
58	x		1070	828	2	3723	21	4	1.040	0.880
59	y		1070	822	2	3653	60	3	1.075	0.853
60	z		1070	830	3	3755	16	4	1.025	0.894
61	x		1337	829	1	2267	16	10	0.885	1.037
62	y		1337	825	3	2224	16	8	0.925	0.990
63	z		1337	828	2	2270	10	7	0.875	1.047
70	x	Super	803	899	3	5079	34	24	0.895	1.021
71	y		803	891	4	5041	62	27	0.885	1.033
72	z		803	898	2	5094	27	7	0.885	1.036
73	x		1069	902	4	4375	37	34	0.885	1.035
74	y		1069	894	3	4360	62	31	0.865	1.060
75	z		1069	901	3	4346	16	12	0.900	1.018
76	x		1337	905	4	2642	21	7	0.785	1.164
77	y		1337	894	4	2538	46	8	0.855	1.071
78	z		1337	904	3	2598	23	12	0.836	1.105

These results were prepared by the Applied Ballistics Department of the Ordnance Board and are fully corrected.

TRAVERSE EFFORTS

The detailed results are as follows:

Occurrence	Direction*	Vehicle Attitude: Front				Left Side				Efforts in lbf at indicated azimuth angle of mortar (mils)								Mean
			°	'	"		°	'	"	0	800	1600	2400	3200	4000	4800	5600	
Before Serial 31	C				Level					4	4	5	4	4	4	5	8	5
	A/C				Level					4	4	4	4	4	4	5	5	4
	C	U	7	30	133	D	18	30	329	8	8	9	6	4	4	4	6	6
	A/C	U	7	30	133	D	18	30	329	5	6	5	5	4	9	6	6	6
After Serial 86	C				Level					6	5	5	4	3	3	6	7	5
	A/C				Level					4	4	4	4	4	3	5	6	4
	C	D	11	3	196	D	12	16	218	6	7	7	6	6	7	10	17	8
	A/C	D	11	3	196	D	12	16	218	6	8	7	10	5	5	6	7	7
After Firing Completed	C				Level					4	4	5	5	4	6	7	6	5
	A/C				Level					6	8	8	5	4	4	5	4	6
	C	U	9	30	169	U	16	2	285	8	6	4	8	8	6	17	11	8
	A/C	U	9	30	169	U	16	2	285	4	8	7	6	5	4	10	5	6

*C = clockwise
A/C = anti-clockwise.

On level ground the mean effort at eight points of traverse was 5 lbf both clockwise and anti-clockwise.

On a severe slope, the mean efforts were 8 lbf clockwise and 6 lbf anti-clockwise.

After allowing for the adverse weather conditions, either blown sand or rain over a period of 10 days, it is evident that the traverse system behaved satisfactorily.

BARREL CLAMP MOVEMENT

The amounts of barrel clamp movement which occurred during the firing of each bomb in Serials 1 to 6, and during the firing of 10 bombs in each of Serials 13 - 86 are shown below.

Serial	Condition of Clamp	QE mil	Charge	Barrel Clamp Movement in inches			Barrel Clamp Closing Effort (lbf)
				Bomb 1	Bomb 2	Bombs 1-10	
1	Soft	1333	5	-0.10	-0.10		35
2		897	5	-0.05	-0.05		
3		1333	P1	-0.10	Nil		
4		901	P1	-0.15	Nil		
5		1333	5	-0.10	Nil		
6		895	5	-0.10	Nil		
13	Hard	1333	5			+0.05	
14		910	5			+0.15	
15		1333	5			-0.10	
16		910	5			-0.10	
17		1333	5			-0.05	
18		910	5			-0.15	
19		1333	5			-0.15	
20		910	5			-0.10	
21		1333	5			Nil	
22		900	5			Nil	
23		1333	5			Nil	
24		900	5			-0.05	
25		1333	5			Nil	
26		900	5			-0.10	
27		1333	5			-0.10	
28		900	5			Nil	
31		800	1			-0.10	
33		800	1			Nil	
34		1066	1			Nil	
36		1066	1			Nil	
37		1333	1			-0.05	
39		1333	1			Nil	
46		1333	3			-0.05	
48		1333	3			Nil	
85		1333	Super			+0.10	30
86		800	Super			+0.5	
40		800	3			Nil	
42		800	3			Nil	
43		1066	3			Nil	
45		1066	3			Nil	
70		800	Super			+1.20	
72		800	Super			+0.55	
73		1066	Super			+1.10	26
75		1066	Super			+0.55	35
76		1333	Super			+0.60	
78		1333	Super			+0.30	
61		1333	5			Nil	
63		1333	5			Nil	
58		1066	5			+0.30	
60		1066	5			Nil	37
55		800	5			Nil	37
57		800	5			Nil	

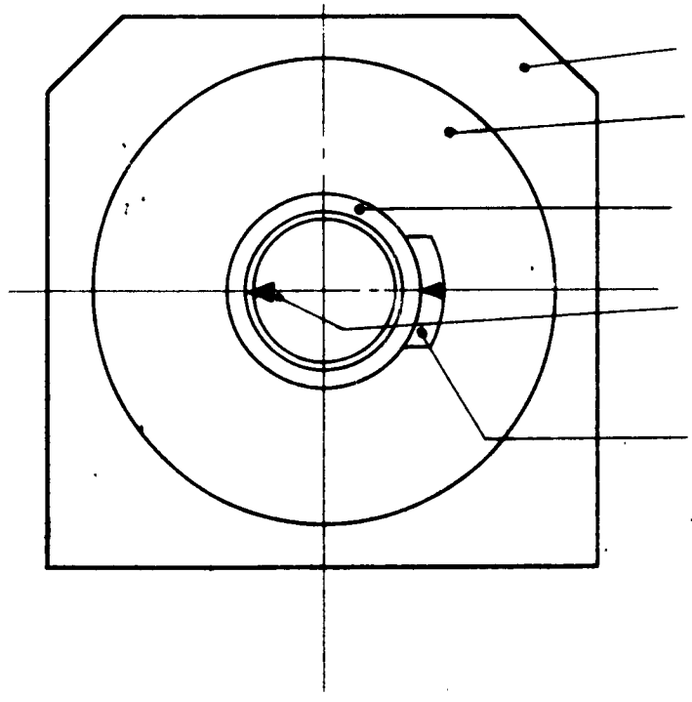
Note: The standard setting for the barrel clamp closing effort is 32-35 lbf.

DEFECTS

A list of the defects, other than those which occurred to the C2 sights, in the order in which they occurred is given below:

Item No.	Occurrences	Part	Serial	After ... Bombs
1	Hatch padding became partially detached.	III	17	108
2	10 mil clockwise movement of azimuth ring.		19	118
3	Three of the locking studs on azimuth ring support loose.		19	118
4	20 mil clockwise movement of azimuth ring.		25	178
5	Azimuth ring support loose, five out of six locking studs missing. (Azimuth ring support was re-fastened by $\frac{3}{8}$in studs.)	IV	48	288
6	Azimuth ring moved 3 mils anti-clockwise.	V	85	298
7	The cross levelling handwheel was considered very loose but functioned correctly.		85	298
8	Mortar heading plate moved 2 mils anti-clockwise		85	298
9	Throwover link pin handle slightly loose.		85	301
10	Mortar heading plate moved clockwise 5 mils		86	303
11	Mortar heading plate moved clockwise 3 mils		86	304
12	Small amount of metal removed from top of elevating screw to prevent fouling in the yoke of the barrel clamp.	IV	45	353
13	Mortar heading plate moved slightly.		72	368
14	$\frac{3}{8}$in studs slightly loose (see item 5)		78	407
15	All traverse gearbox holding down bolts found to be loose.		56	458
16	During the post trial inspection it was found that the felt seal between the platform and the base had permitted the ingress of a considerable quantity of sand.			

The terms "azimuth ring", "vehicle heading plate" and "mortar heading plate" may be confusing. It is hoped that the diagram shown overleaf will provide the necessary clarification.


Adapter base bolted to hull.
Adapter turntable.
Adjustable azimuth ring of 6,400 mils fitted with screw lock.
Vehicle heading plate fixed through a centre pivot to adapter base.
Mortar heading plate fixed to turntable and provided with a small amount of adjustment to enable it to be zeroed during installation of the adapter.

DEFECTS TO C2 SIGHTS

J 1 Bombs as indicated below were fired with the respective C2 sights:

Sight No.	Charge					Totals
	1	3	4	5	Super	
82	60	32	12	180	-	284
101		40		65	60	165

J 2 The following incidents happened to the sights.

Sight No.	Detail	Part	Serial	After ... Bombs
82	Sight jumped in traverse 150 mils.	II	9	26
	Rubber eye piece came off.	III	21	127
	Elevation screw and traverse control slightly stiff in several places.	III	26	184
	Elevation locking lever accidentally damaged during the removal of the sight from the mounting.	IV	48	284
101	Sight fell off.	V	85	6
	Rubber eye piece came off.	IV	45	65
	Sight became partially unlatched.	IV	70	72
	Sight became wholly unlatched.	IV	70	73
	Lens on telescope became damaged (exchanged for one off sight 82).	IV	75	103

J 3 D.I. Arm (FCI) Inspection.

The sights were inspected by D.I. Arm after the trial when it was discovered that both sights suffered a common failure in that the elevation and azimuth worm shafts were bent.

For D.I. Arm report see Annex 1 to this Appendix.

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APPENDIX J
ANNEX 1
Sheet 1

REPORT BY D.I. ARM (FIRE CONTROL INSTRUMENTS BRANCH) ON THE C2 SIGHTS, DECEMBER, 1964.

1. PRELIMINARY VISUAL EXAMINATION.

1.1 Serial No. 82.

Elevation - locking lever thread sheared, allowing excessive play and backlash between worm and wheel.

Azimuth - locking screw dented, azimuth knob bruised.

Telescope - prism loose in mount. O.G. end of telescope dented.

1.2 Serial No. 101.

Azimuth - wing nut of locking screw fractured.

Dovetail - end bruised.

Light source illuminating cross level - brackets loose.

2. SPECIFICATION TEST (PRIOR TO BREAKDOWN ONLY).

For the purpose of testing Sight, Serial No. 82, it was necessary to borrow the following parts from Sight Serial No. 236:

Telescope
Elevation locking lever

Leaf spring
Washer
Ball Retaining Plate
} Missing from sight on arrival at F.C.I.

Results of these tests, including scale setting errors are shown at Sheets 3 and 4 of this Annex.

3. PHYSICAL EXAMINATION.

Following the specification tests, Sight, Serial Nos 82 and 101, were dismantled for physical examination.

Results of Examination.

3.1 Serial No. 82.

3.1.1 Elevation — Worm wheel - the teeth showed no apparent signs of wear or damage.
Worm shaft - this was bent - see sheets 5 and 6 for details and graph.

3.1.2 Azimuth — Worm wheel - the tops of the teeth showed slight wear, but no apparent damage.
Worm shaft - this was bent - see sheets 5 and 6 for details and graph.

3.1.3	Telescope	The bonding between prism and mount had fractured, and the prism was badly chipped. From examining the telescopes of both sights it was noted that the undamaged prism mounting was to drawing No. A376610, which is of a stronger design than that of the mount which suffered a fractured bond, Drawing No. A303319. See Sheet 7.

3.2 Serial No. 101

3.2.1	Elevation	Worm wheel - this showed no apparent wear or damage. Worm shaft - this was bent - see sheets 5 and 6 for details and graph.
3.2.2	Azimuth	Worm wheel - this showed no apparent wear or damage. Worm shaft - this was bent - see sheets 5 and 6 for details and graph.
3.2.3	Telescope	No apparent damage (see sheet 7 for method of mounting prism).

It was noted that Sights, Serial Nos. 82 and 101, were returned to F.C.I. Branch with the telescopes interchanged.

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ANNEX 1
Sheet 3

RESULTS OF TESTS TO SPEC. CA-A143, ISSUE 3 (CANADIAN ARMY)

Specn. Para No.	Description of Test	Result of Test Serial No. 82	Result of Test Serial No. 101	Tolerance
4.2.1	Magnification	X 1.75	X 1.8	X 1.8 ± 5%
4.2.2	Field of view	183 mils	183 mils	180 mils ± 5%
4.2.3	Definition	Satisfactory	Satisfactory	No apparent distortion over $\frac{2}{3}$ of field of view (minimum).
4.2.4	Eyepiece focus	Vertical -1.5	Vertical -1	-0.75 to -1.0 Dioptre.
4.2.5	Verticality of Reticule	Within tolerance	Within tolerance	±2 mils.
4.2.6	Parallax	Slight	Nil	No apparent movement at 100 yards ±10 yards.
4.2.7	Collimation (a)	Satisfactory	Satisfactory	No apparent displacement.
	(b)	Satisfactory	Satisfactory	No apparent displacement.
	(c)	Within tolerance	Within tolerance	±10 mils.
4.2.8	Plumb travel	Satisfactory	Satisfactory	2 mils.
4.2.9	Horizontal travel 0°	0	0	±2 mils throughout one full revolution.
	90°	-3.5 mils	-4.4 mils	
	180°	0	0	
	270°	+2.9 mils	+5 mils	
	360°	0	0	
4.2.10 4.2.11	Azimuth error / Elevation error	See sheet 4		±2 mils inclusive of backlash
4.2.12	Azimuth Micrometer	Satisfactory	Satisfactory	
4.2.15	Levels, Vials	Cross Level 1½ graduations	Cross Level 3 graduations	±½ graduation
	Light transmission	75%	83%	

Note: Eyepiece focus. Due to the design of this component the focus increases from left to right of the vertical position, to the extend of ½ dioptre on No. 82 and ¾ dioptre on No. 101.

Scale Setting (Milliemes)	Serial No. 82			Serial No. 101		
	DEPARTURE FROM SCALE SETTING					
	Increasing Reading	Decreasing Reading	Backlash Error	Increasing Reading	Decreasing Reading	Backlash Error
0	0	+0.4	0.4	0	+0.55	0.55
800	+0.2	+0.65	0.45	0	+1.2	1.2
1600	+0.3	+0.9	0.6	-0.6	+0.2	0.8
2400	+0.25	+0.5	0.25	-0.85	+0.5	1.35
3200	+0.3	+0.55	0.25	-0.75	-0.15	0.6
4000	+0.1	+0.6	0.5	-1.2	-0.4	0.8
4800	-0.55	+1.1	1.65	-1.0	-0.4	0.6
5600	-0.35	+0.4	0.75	-0.55	+0.1	0.65
6400	0	+0.45	0.45	0	+0.45	0.45
Mortar Scale						
600	-0.6	+0.45	1.05	-0.4	+0.15	0.55
800	0	+0.45	0.45	0	+0.4	0.4
1200	-0.6	+0.3	0.9	-0.15	+0.3	0.45
1600	-0.8	-0.2	0.6	-0.8	+0.2	1.0
Machine Gun Scale						
-200	+0.1	+0.55	0.45	+0.6	-0.2	0.8
0	0	+0.2	0.2	0	-0.4	0.4
200	+0.15	+0.2	0.05	-0.1	-0.4	0.3
400	+0.1	+0.2	0.1	+0.35	-0.35	0.7
600	+0.3	+0.4	0.1	+0.45	0	0.45

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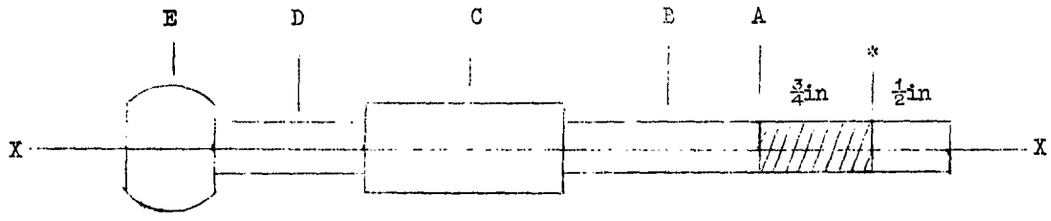
Sheet 5

DETAILS OF BENDING OF WORM SHAFTS OF C2 SIGHTS SERIAL NOS. 82 AND 101



Dimensions in inches.

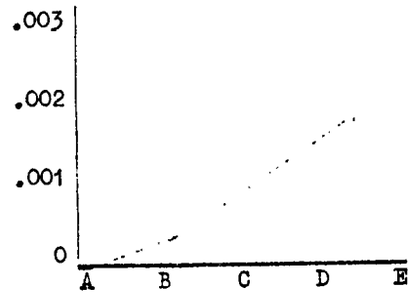
Components were held at the shaded portion in a precisely set collet and rotated until maximum deviation from a true axis 'XX' at position 'E' was located. Intermediate amounts of deviation were then noted.

Position A is at collet face
Position B is 0.15 from collet face
Postiion C is 0.52 from collet face
Position D is 0.925 from collet face
Position E is 1.350 from collet face

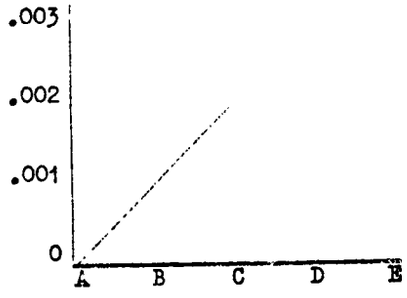
Position	Serial No. 82		Serial No. 101	
	Elevation	Azimuth	Elevation	Azimuth
A	0	0	0	0
B	.0002	.0011	.0010	.0009
C	.0010	.0021	.0034	.0019
D	.0015	.0023	.0048	.0015
E	.0022	.0026	.0062	.0011

GRAPHS INDICATING DEVIATION FROM TRUE AXIS OF WORM SHAFTS

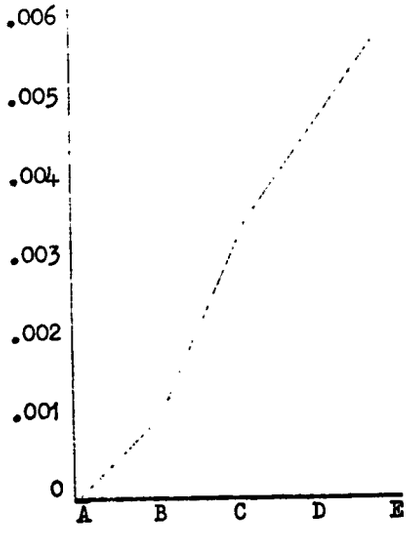
Deviation (inches)



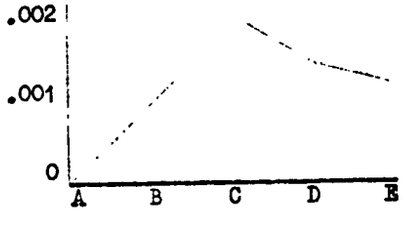
Serial No. 82
Elevation



Serial No. 82
Azimuth



Serial No. 101
Elevation



Serial No. 101
Azimuth

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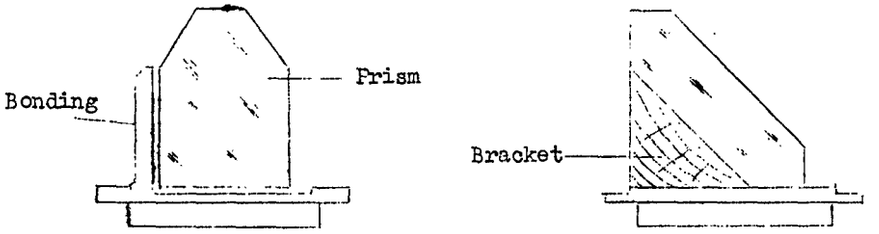
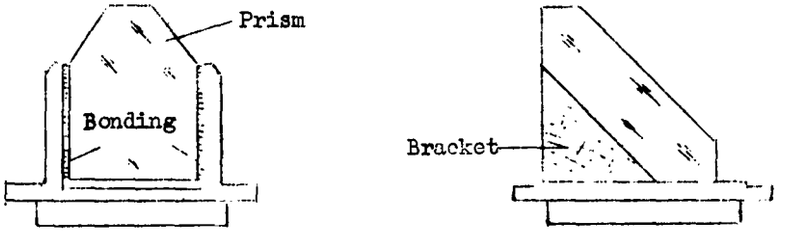
SKETCHES ILLUSTRATING MAJOR DIFFERENCES
BETWEEN TWO TYPES OF PRISM MOUNTINGS
see Para 3.1.3.

FIG. 1



Drawing A303319 dated 10.4.63

FIG. 2



Drawing A376610 dated 28.6.63

MISCELLANEOUS NOTES

K 1 **Misfire.**

During Part IV a misfire occurred. The correct drill was applied and the firing pin was removed without disturbing the mortar. The bomb was then safely extracted by the special tool developed by the Trial and Development Wing, School of Infantry.

The misfire was found to be a genuine failure of the primary cartridge.

K 2 **Buffers.**

The movement of the buffers was checked by the aid of plasticine that no bottoming occurred and was measured on three occasions.

Serial	Downward Movement of Mounting Buffers	Run out of Barrel Buffer
44	0.125in	0.25in
62	0.20 in	0.375in
57	0.55 in	0.3 in

K 3 **Throwover Link**

Throughout the trial the throwover link was forward at QEs of 800 mils and back for QEs of 1066 and 1333 mils.

EQUIPMENT DETAILS

Vehicle: FV.432 W7 No. 03 EA 76

81mm Mortar used in FV.432 L1A1 No. 3068) for measurements see
81mm Mortar used on ground L1A1 No. 3069) Annex to this Appendix.

Adapter: F.V.R.D.E. Prototype No. 1 (FV.573051).

Mounting 81mm Mortar: L5A2 No. 9.

Base plate 81mm Mortar: C.D.N. Mk. 1 No. 605.

Ammunition:

Requisition FVRDE/PROV/80227.
100 bombs filled HES, fitted inert fuse 162, and cartridged super-charge (one primary L30A1, two medium 825 grains, one small 220 grains ball powder per bomb).

Requisition FVRDE/PROV/80255.
250 bombs filled HES, fitted inert fuse 162 and cartridged L15A1 (Mk. 1 System one primary L30A1, two augmenting L31A1, 465 grains, three augmenting L32A1, 180 grains, per bomb).

200 bombs filled HES, fitted inert fuse 162 and cartridged super-charge (one primary L30A1, four augmenting at 465 grains ball powder per bomb).

The balance of the ammunition used came from requisition FVRDE/PROV/80186 and cartridged L15A1.

Proof charge P1 = Charge 5 (Mk. 1 System) i.e. 1470 grains + 250 grains.

REPORT TR.80
APPENDIX L
ANNEX

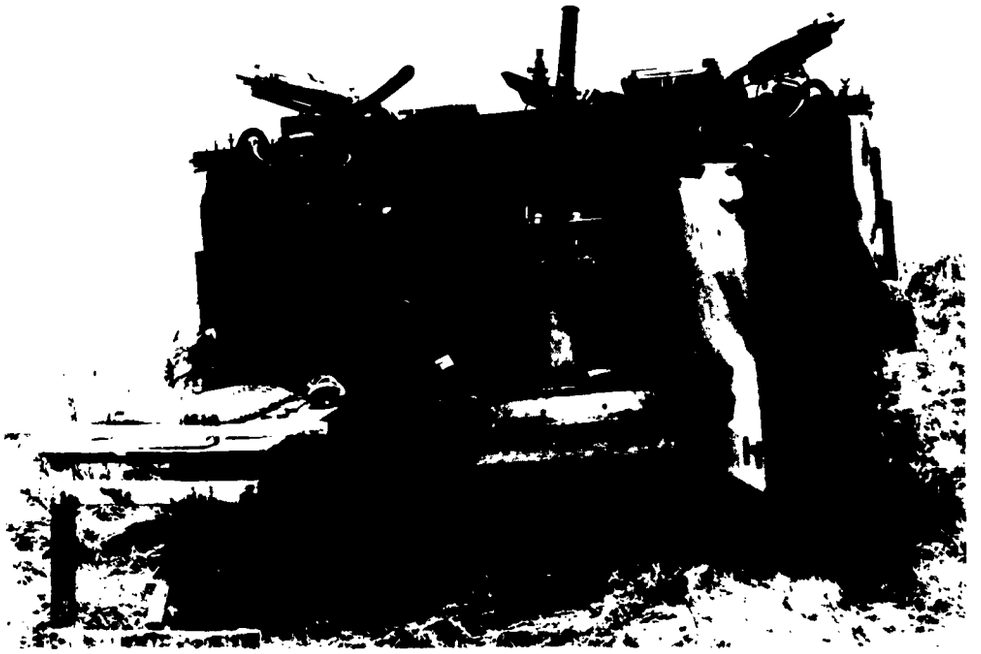
BORE DIAMETERS (Inches)

Barrel L/3068 (Vehicle)

Inches from Muzzle (a)	Before Trial		After Trial		After Firing	
	Hor. (b)	Vert. (c)	Hor. (d)	Vert. (e)	Diff. from col(b) (f)	Diff. from col (c) (g)
1	3.207	3.207	3.207	3.207	Nil	Nil
3	3.207	3.207	3.207	3.207	Nil	Nil
6	3.206	3.206	3.207	3.207	+0.001	+0.001
12	3.206	3.206	3.206	3.206	Nil	Nil
24	3.206	3.206	3.206	3.206	Nil	Nil
30	3.206	3.206	3.206	3.206	Nil	Nil
36	3.206	3.206	3.206	3.206	Nil	Nil
42	3.206	3.206	3.206	3.206	Nil	Nil
44.5	3.205	3.205	3.205	3.205	Nil	Nil

Barrel L/3069 (Ground)

Inches from Muzzle (a)	Before Trial		After Trial		After Firing	
	Hor. (b)	Vert. (c)	Hor. (d)	Vert. (e)	Diff. from col(b) (f)	Diff. from col(c) (g)
1	3.207	3.207	3.208	3.206	+0.001	-0.001
3	3.207	3.207	3.207	3.207	Nil	Nil
6	3.206	3.206	3.206	3.206	Nil	Nil
12	3.206	3.206	3.206	3.206	Nil	Nil
24	3.206	3.206	3.206	3.206	Nil	Nil
30	3.206	3.206	3.206	3.206	Nil	Nil
36	3.206	3.206	3.206	3.206	Nil	Nil
42	3.206	3.206	3.206	3.206	Nil	Nil
44.5	3.205	3.205	3.205	3.205	Nil	Nil



A217/2/64

FIG. 1

IN POSITION PRIOR TO PART III
ENDURANCE AND ASSESSMENT OF PHYSIOLOGICAL EFFECTS

A217/1/64

FIG. 2

IN POSITION PRIOR TO PART III
ENDURANCE AND ASSESSMENT OF PHYSIOLOGICAL EFFECTS

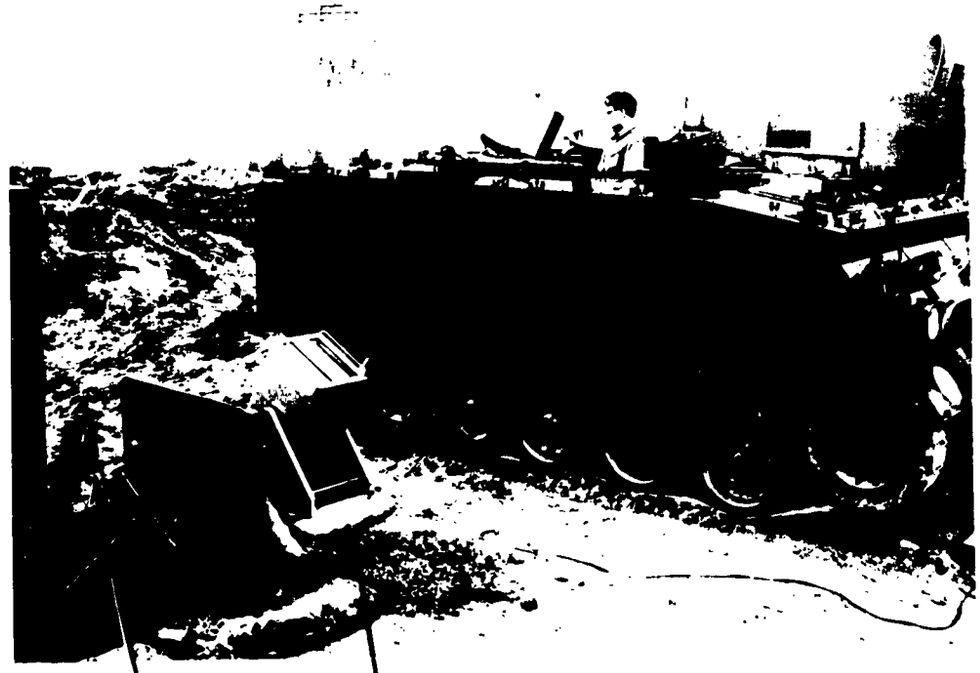
A217/4/64 FIG. 3

Sgt Macdonald L/c Parker - No. 2 Pte Phipps - No. 1
i/c detachment Layer Loader

All of 2nd Bn The Parachute Regiment.

PRIOR TO THE COMMENCEMENT OF
PART III
ENDURANCE AND ASSESSMENT OF PHYSIOLOGICAL EFFECTS

During firing Sgt Macdonald controlled the ammunition supply and L/c Parker and Pte Phipps wore Ear Defenders Mk. 3.



A226/5/64

FIG. 4

Ground mounted mortar

EVA aerial

QMSI P. Alexander who laid all the bombs fired in the R & A serials.

C226/2/64 FIG. 5

QMSI L. Shepherd waiting to load.

QMSI K. Pinkard laying.

C226/3/64 FIG. 6

QMSI Shepherd loading.

QMSI Pinkard watching the bubbles in the sight.

C226/4/64 FIG. 7

Firing

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Date of Search: 18 November 2008

Record Summary: WO 194/483
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